

Warsaw Variability Surveys

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Abstract. Four large/medium size photometric surveys are being conducted by Warsaw astronomers: Warsaw-LCO survey of globular clusters, OGLE, DIRECT and ASAS. In this contribution we provide short description of these projects and discuss briefly some results obtained for pulsating variables.

1. Warsaw-LCO survey of globular clusters

The main goal of the survey is identification of detached eclipsing binaries in globular clusters. Such binaries can be used as excellent distance and age indicators (Paczynski 1997). Thirteen globular cluster were surveyed since 1993. Starting with 1997 most of the data are collected with the Las Campanas 1.0m Swope telescope equipped with SITe 2048×3150 CCD giving field of view 14.4×22.8 arcmin². Some additional follow-up observations are conducted on the 2.5m du Pont telescope. For a given cluster the total length of monitoring ranges from 30 to 150 hours with the median value around 70 hours.

Precise and well sampled light curves of RR Lyr and SX Phe stars are collected as a side result of the survey. These data become available through Internet (<http://sirius.astro.uw.edu.pl/~jka/>) immediately after results for a given object are published. A list of monitored clusters and numbers of variables identified in them are given in Table 1. While monitoring M55 we identified five variables being likely members of the Sagittarius dwarf galaxy: two RRab stars and three SX Phe variables.

1.1. Non radial pulsators in M55

Our sample of pulsating variables from the globular cluster M55 includes five newly identified RRc stars. The light curves of three of these stars exhibit changes in amplitude of over 0.1 mag on the time scale shorter than a week. Detailed analysis indicates that observed changes are most probably due to non radial pulsations (Olech et al. 1999).

At least 12 out of 24 SX Phe variables identified in M55 show a presence of two or more periodicities in their light curves. Table 2 lists principal periods, ratio P_1/P_2 and amplitudes for first terms of Fourier series calculated for both periods after appropriate pre-whitening was applied. The derived values of P_1/P_2 indicate that we are dealing with non radial pulsations. In Fig. 1

Table 1. Pulsating variables detected in the monitored GCs

| Cluster | RR Lyr | SX Phe | Reference |
|--------------|--------|--------|-------------------------------|
| ω Cen | 132 | 34 | Kaluzny et al. (1997, 1997a) |
| NGC 288 | 3 | 5 | Kaluzny et al. (1997b) |
| NGC 4372 | 0 | 8 | Kaluzny et al. (1993) |
| NGC 6397 | 1 | 2 | Kaluzny (1997) |
| NGC 6362 | 18 | 4 | Mazur et al. (1999) |
| | 35 | 4 | Kaluzny et al. in prep |
| NGC 6752 | 0 | 3 | Thompson et al. (1999) |
| M3 | 42 | 1 | Kaluzny et al. (1998) |
| M4 | 31 | 0 | Kaluzny et al., in prep. |
| M5 | 99 | 5 | Kaluzny et al. (1999a, 1999b) |
| | | | Olech et al. (1999a) |
| M10 | 1 | 3 | Kaluzny et al., in prep. |
| M55 | 13 | | Olech et al. (1999) |
| | | 24 | Kaluzny et al. in prep. |
| Ru 106 | 12 | 3 | Kaluzny et al. (1995) |
| Total | 387 | 96 | |

we present light curves obtained on two consecutive night for one of the multi-periodic SX Phe stars from M55. We note that also light curve of an SX Phe variable identified in M3 by Kaluzny et al. (1998) exhibits evidence for non radial pulsations of that star.

Table 2. Multi-modal SX Phe stars in M55

| ID | P1[d] | P1/P2 | A_1^1 | A_1^2 |
|-------|--------|-------|---------|---------|
| 19336 | 0.0388 | 1.017 | 0.020 | 0.009 |
| 19407 | 0.0415 | 1.023 | 0.048 | 0.019 |
| 25078 | 0.0593 | 1.034 | 0.027 | 0.018 |
| 25204 | 0.0370 | 1.026 | 0.014 | 0.006 |
| 31780 | 0.0487 | 1.075 | 0.035 | 0.010 |
| 34347 | 0.0394 | 1.054 | 0.033 | 0.012 |
| 34461 | 0.0438 | 1.023 | 0.025 | 0.011 |
| 19084 | 0.0382 | 0.974 | 0.029 | 0.012 |
| 12618 | 0.0358 | 1.049 | 0.017 | 0.008 |
| 15539 | 0.0370 | 1.067 | 0.014 | 0.007 |
| 19176 | 0.0452 | 1.239 | 0.053 | 0.024 |
| 19480 | 0.0367 | 1.029 | 0.026 | 0.017 |

1.2. M3/M55 dichotomy

Our sample of monitored clusters includes M3 and M55. These objects have similar metallicities and exhibit similar morphology of their color-magnitude

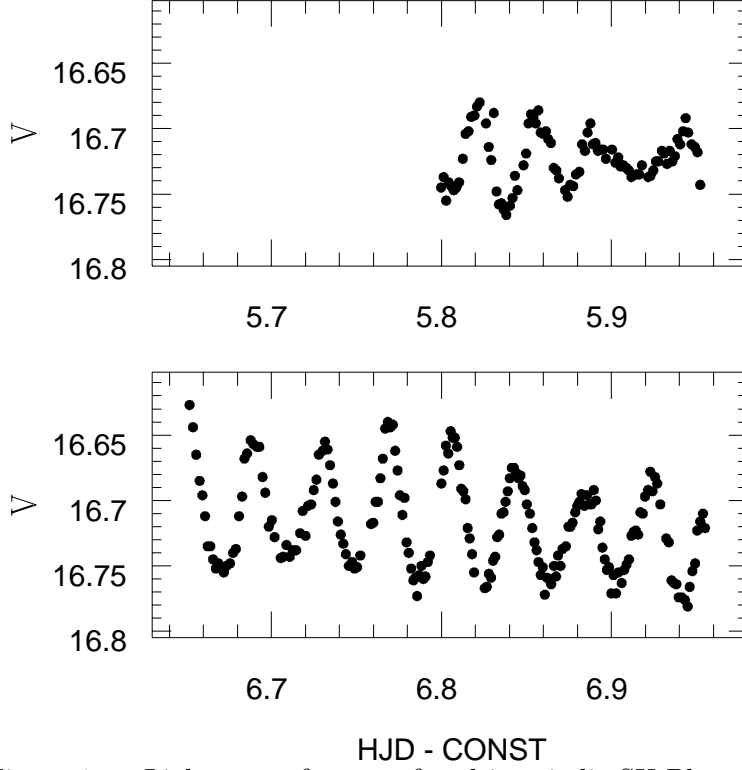


Figure 1. Light curve for one of multi-periodic SX Phe stars from M55.

diagrams (in particular horizontal branches are similar to each other). Both cluster are rich in blue stragglers yet show very different relative frequencies of SX Phe stars. This can be illustrated by comparing numbers of blue stragglers for which we obtained good quality light curves with numbers of identified SX Phe stars:

M55: $N_{BS} = 40$, $N_{SX} = 24$, $[Fe/H] = -1.81$

M3: $N_{BS} = 25$, $N_{SX} = 1$, $[Fe/H] = -1.57$

Our data for M3 show several blue stragglers located inside instability strip which do not show any variability exceeding about 0.02 mag in the V band.

1.3. How complete is a sample of SX Phe stars identified in GCs?

Figure 2 shows full amplitude versus period diagram for 96 SX Phe stars identified by our group in globular clusters. 53 out of these stars exhibit light curves with full range not exceeding 0.10 mag in the V band. Many variables show amplitudes approaching detection limit of our survey which, for most clusters reaches 0.02 – 0.03 mag. That indicates that a significant fraction of SX Phe stars residing in surveyed cluster was most likely missed.

2. OGLE-1 survey

The OGLE project (Udalski et al. 1993; <http://sirius.astro.uw.edu.pl/~ftp/ogle/>) is aimed primarily at detection and photometry of microlensing events in the

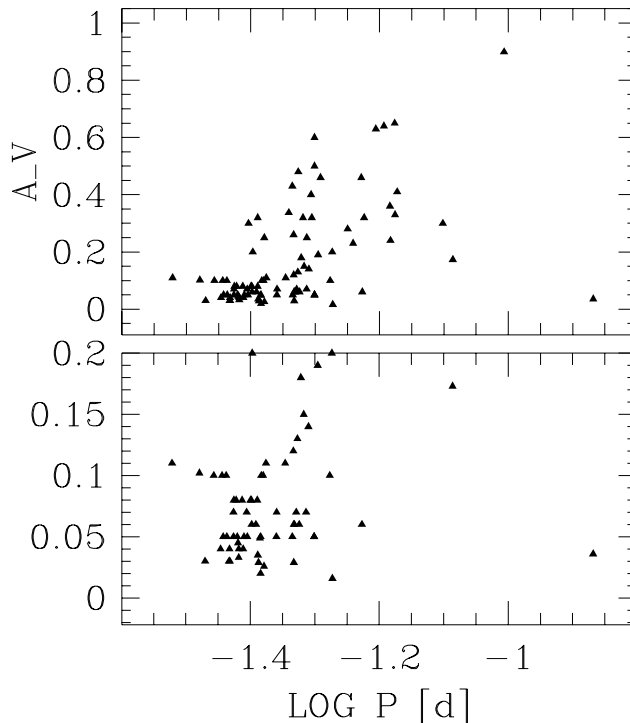


Figure 2. Full amplitude versus period for SX Phe stars identified during our survey of globular clusters.

Galactic bulge and LMC/SMC. The first phase of the survey, refereed here as OGLE-1, was conducted at Las Campanas Observatory on the 1.0m Swope telescope during 4 seasons covering the period 1992-1995. About 2×10^6 stars in 20 15×15 arcmin² fields toward the Galactic bulge were monitored. 20 microlensing events were detected (Wozniak & Szymanski 1998). Five parts of the Variable Star Catalog were published, containing 2861 stars from the Galactic bulge (Udalski et al. 1997a). That catalog includes 269 pulsating objects, mostly RR Lyr stars.

Several side projects were attempted by the OGLE-1 team. We list here these of them which yield some possibly interesting results for pulsating variables. Mateo et al. (1995) searched with success for RR Lyr stars belonging to the Sagittarius dwarf galaxy. They reported VI photometry for 7 variables from that galaxy. V band data for 226 RR Lyr stars from the Sculptor dSph galaxy were obtained by Kaluzny et al. (1995a). That galaxy may prove to be an ideal target for calibration of the luminosity-metallicity relation for RR Lyr stars. Population of stars hosted by Sculptor shows significant range of metallicities and the interstellar reddening toward the galaxy is very low. Kaluzny et al. (1996, 1997) identified 34 SX Phe stars in the globular cluster ω Cen. V band data for 141 RR Lyr stars (33 newly identified) and Pop II Cepheids in the same cluster were published by Kaluzny et al. (1997a).

In 1996 the OGLE project entered its second phase known as OGLE-2 (Udalski, Szymanski & Kubiak 1997). OGLE-2 results are described in this volume by Paczyński (1999).

3. DIRECT

The DIRECT project (<http://cfa-harvard.edu/~kstanek/DIRECT/>) aims at determination of distance to M31 and M33 galaxies by using detached eclipsing binaries and Cepheids. The project is currently conducted by a group including astronomers from CfA and Warsaw. About 200 nights on the 1.2m FLWO and 1.3 MDM telescopes were used between September 1996 and November 1999 to search both galaxies for variables suitable for more detailed follow-up. So far five catalogs of variables in M31 were released (Kaluzny et al. 1998a, 1999; Stanek et al. 1998, 1999; Mochejska et al. 1999). 410 variables (most of them new) were identified, including 206 Cepheids and 48 eclipsing binaries. Photometry of many RV Tau and LPV stars was also reported. The remaining catalogs shall be released over the coming year. Some results of DIRECT concerning Cepheids are presented in this volume by Sasselov (1999)

4. ASAS

ASAS (the All Sky Automated Survey; Pojmanski 1997; <http://www.astrouw.edu.pl/~gp/asas>) is a project which ultimate goal is low cost monitoring of the whole sky on a nightly basis down to about 15 magnitude. A prototype robotic telescope consisting of the 135mm telephoto lens, off-the-shelf CCD camera (512 x 768 pixels) and small automated mount was set up at the Las Campanas Observatory in April 1997. It has been monitoring 24 selected fields covering about 150 deg² of the sky. Useful photometry in the I band was obtained for over 45000 stars brighter than 13 magnitude. The first two month of observation revealed 126 short period variables (Pojmański 1998), of which 70 % were previously unknown. The catalogue includes several newly identified RR Lyr stars and Cepheids. In 1998 the survey was extended to cover additional 150 deg² and the updated version of the catalogue will include data for a large number of pulsating stars with periods up to 300 days (Pojmanski 1999, private communication). At the end of 1999 two new robotic telescopes with 2K² CCD's will be installed at Las Campanas.

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